Blockchains for circular plastic value chains

KOLADE, Seun <http://orcid.org/0000-0002-1125-1900>

7

BLOCKCHAINS FOR CIRCULAR PLASTIC VALUE CHAINS

Oluwaseun Kolade

1 Introduction

The plastic value chain comprises four key phases: design, production, use and end of life. An effective discussion of the merits and potentials of the circular plastic economy must be underpinned by a whole value chain approach. Currently, most of the scholarly research on plastic pollution, and much of the ongoing campaigns to tackle the same, have typically focused on the end-of-life phase (Johansen et al., 2022). However, the problems and potentials of plastic waste do not begin at the end-of-life phase, where the efforts are effectively restricted to mitigation rather than prevention and control of the plastic waste problem. This chapter therefore begins with a review of the plastic value chain, with critical reflections on the different and comparative implications, at each of the phases, for the linear and circular economy models.

The plastic value chain begins at the design phase. The design of plastic products, or plastic parts in composite manufactured products, typically follows the Design for Manufacture and Assembly (DFMA) framework. Designers often use the injection moulding process which allows the manufacture of custom products and components of varying sizes and thickness (Karania et al., 2004). It is during the design phase that key decisions are taken about the operational features, functional properties and quality of the final product. These include questions of polymer mix and recyclability, which are key considerations for circularity of the final product. The traditional paradigm for design of plastic products allows designers to mix different polymers, as well as incorporate various combinations of additives, coolants and adhesives in the manufacture of plastic products. The resulting final products are therefore too customised and complex that they are hardly suitable for recycling (Plastic Ocean, 2022). The design of circular plastic products should therefore be based on standardised, simpler materials and fewer

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polymer types in order to enhance their future recyclability (Johansen et al., 2022). Thus, ecodesign of circular plastic products are undergirded by five key principles: design for sustainable sourcing, design for optimised resource use, design for environmentally sound and safe product use, design for prolonged product use and design for recycling (Foschi et al., 2020).

The production phase of the plastic value chain includes the extraction and production of raw materials, the production of primary plastics and the production of secondary plastics. The vast majority of plastic products – with some estimates putting it at 99% – are currently derived from petrochemicals sourced from fossil fuels, with the remaining estimated 1% produced from bio-based materials (James, 2017). As national policies and multilateral initiatives gather momentum to restrict the use of petrochemicals, the proportion of renewable biomaterials used in making plastics is likely to increase in the future. Primary plastic production focuses on the production of primary plastic pellets (primary microplastics), which are either produced as monomers for in-house conversion by large companies or otherwise sold to other companies to polymerise at a smaller scale (James, 2017; Ryberg et al., 2018). The production of plastic products is undertaken through the melting and moulding of primary plastics (Johansen et al., 2022). The five types of primary plastics that account for most of the global plastic production are polyethylene terephthalate (PET), high-density polyethylene (HDPE), polyvinyl chloride (PVC), low-density polyethylene (LDPE) and polypropylene (PP) (James, 2017). The production of secondary plastics relates essentially to plastic waste management via recycling of primary plastics.

The use phase of the plastic value chain spans a wide spectrum of sectors including containers and packaging, engineering and construction, consumer goods, industrial machinery, transportation and textiles (James, 2017). The activities in this phase include demand and purchase, use and post-consumption handling of plastic products (Johansen et al., 2022). Demand and purchase patterns are often influenced by consumers' levels of awareness and understanding of environmental impact of the plastic products and knowledge of alternative, more environment-friendly products (Boesen et al., 2019). Policy and regulatory factors also influence societal habits of consumption, for example, through incentives and support for alternative products and packaging (Kolade et al., 2022b; Oyinlola et al., 2022) and through various levies and taxes on plastic bags, especially single-use plastics (Syberg et al., 2021).

The end-of-life phase is the phase that has currently attracted the most attention in the plastic value chain. This phase includes a wide range of activities, processes and factors, including collection and sorting, recycling, life cycle assessment and policy and regulations (Johansen et al., 2022). Increasing the rate of plastic waste collection is an important step needed to divert plastic wastes from landfills, thereby ensuring cleaner waste streams (Syberg et al., 2021). In order to realise this desirable outcome for a circular plastic economy, the responsibility for collection needs to be shared by producers and incentivised by appropriate regulations (European Union, 2018). One of the instruments that has been used to encourage collection and subsequent recycling of plastic products is the deposit refund system (DRS). This is a market-based instrument in which the consumer is required to pay an extra amount of money as deposit for product packaging at the point of purchase, and this deposit is then refunded at the point of return of the container (Sanabria Garcia and Raes, 2021). An effective and efficient plastic waste collection system is an important first step that determines the success of subsequent activities, including sorting and recycling.

Plastic recycling can be either mechanical or chemical. The main difference between the physical and chemical methods of plastics recycling is that physical recycling does not entail any alteration of the structure and composition of the polymer material of which the plastic product is composed (Martinez Sanz et al., 2022). On the other hand, chemical recycling typically involves changes in the polymer structure, including depolymerisation of polymers into monomers, from which they are subsequently purified and returned into the polymerisation process towards the making of new products. As mentioned above, the original structure of the initial product comes into play at this point, as complex polymers, including those with additives and adhesives, are much more difficult to chemically break down in the process of making new products. The more viable option for such products is physical recycling, although this in effect offers more limited product options in recycling.

The preceding review underlines the intricate linkages across the different phases of the plastic value chain (see Figure 7.1 for an overview of the four phases). The design of plastic products around simpler, more standardised polymer structures has a direct impact on the recyclability of the final product. In terms of production, the drive towards the use of renewable biomaterials in the production of biodegradable plastics can make an increasingly substantial contribution to the global campaign to reduce plastic wastes (Goel et al., 2021). The specific structure of the material produced also influences the type of recycling methods suitable for the end-of-life phase of the product. Thermoplastic polymers, for example, can be easily recycled, either through mechanical processes or chemical processes such as chemolysis, cracking or gasification (Morici et al., 2022). On the other hand, thermoset plastics are more difficult to recycle because they are heat and chemical resistant and usually require high energy input.

Given the foregoing, a multi-stakeholder, multi-sectoral approach is required, across the key phases of the plastic value chain, to accelerate the transition to a circular plastic economy. Digital innovations can play a key role in facilitating this collaborative synergy of stakeholders. This chapter focuses attention on blockchains as an especially auspicious Industry 4.0 technology that potentially has applicability across the entire plastic value chain. In order to explicate this, this chapter takes a conceptual approach with a case illustration to explore the merits and limits of blockchains as a driver of a circular plastic economy on the African continent. The rest of this chapter is organised as follows: first, this chapter provides a review of the relevance and application of blockchains in the circular economy, before zeroing in on the applications of blockchains in the plastic value chain. This

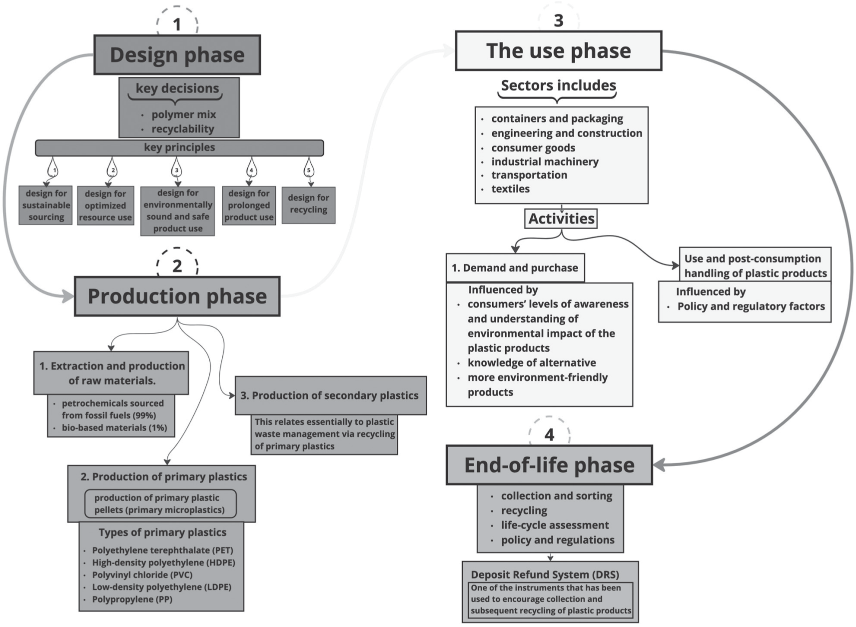

FIGURE 7.1 The four phases of the plastic value chain (author)

is then followed with a case study of BanQu, a blockchain solution launched in partnership with Coca-Cola Africa to improve local recycling and drive a circular plastic economy in South Africa. This chapter ends with a discussion, conclusion and recommendations.

2 Blockchains, circular economy and plastic value chains

2.1 Blockchains and the circular economy

Blockchains are defined as "tamper evident and tamper resistant digital ledgers implemented in a distributed fashion and usually without a central authority" (Yaga, Mell, Roby, and Scarfone, 2018, p. iv). Blockchains are thus characterised by the principles of decentralisation, persistency, anonymity and auditability (Zheng et al., 2017). In place of a centralised third-party intermediaries (such as central banks), blockchains deploy consensus algorithms to maintain data consistency in a distributed system (Kolade et al., 2022a). The anonymity, autonomy and interoperability of blockchains enable separate parties to efficiently and seamlessly share data and synchronise their services in a process that is tamper resistant but does not require trust among the parties (Sanka et al., 2021).

Although it was originally developed within the context of financial systems (Lee, 2019), blockchains have gained increasing traction among scholars, practitioners and campaigners for the circular economy. It has been noted that a digital solution that enables transparent sharing of information about materials and supply chains can facilitate more circular resource flows (Böckel et al., 2021). It can also facilitate a meeting point of stakeholders and a melting pot of ideas to accelerate the transition to a circular economy.

With regard to the supply chains, blockchain technology can enable the transformation of traditional supply chains to circular supply chains in order to optimise resource allocation and promote sustainability (Huang et al., 2022). Blockchains integrate the three key supply chain reverse processes – recycle, redistribute and re-manufacture – with the three key factors that underpin blockchain technology: trust, traceability and transparency (Centobelli et al., 2022). It can be used to manage, share and monitor key product information such as quality, quantity, location and ownership (Centobelli et al., 2022) and other important parameters such as product demand, transaction price, delivery period, resource recycling rate and greenhouse gas emissions (Huang et al., 2022). These are all of critical interest to supply chain stakeholders.

In addition to supply chain applications, blockchains have also been deployed to create and manage new circular economy ecosystems through the use of tokens (Narayan and Tidström, 2020). Tokens are digital assets that can be transferred between parties in a decentralised system, and they can be exchanged for fiat currencies. Blockchain tokens can be used to incentivise consumers to return products or recycle wastes (Rejeb et al., 2022). Tokens can therefore be used to integrate otherwise disconnected product ecosystems and thereby support the transition from linear, competitive models of value creation and appropriation to circular, co-opetitive models of value circulation among stakeholders (Narayan and Tidström, 2020). Incentivisation opportunities, created via tokens, are used to support new product uptake, testing and validation (Nandi et al., 2021). They can also be used to integrate actors from low-income communities and poorer households to the circular economy.

2.2 Applications of blockchains in the plastic value chain

Following on from the discussion of the general merits of blockchains in the circular economy, this section now turns attention to the application of blockchain in the plastic value chain. The introductory section has identified the four key phases of the plastic value chain, namely the design phase, the production phase, the use phase and the end-of-life phase. This section will highlight and discuss the applicability and potentials of blockchains in each of these four phases (Figure 7.2).

2.2.1 The design phase

One of the main talking points in the drive towards a circular plastic economy is the challenge of holding plastic manufacturers to account on promises to

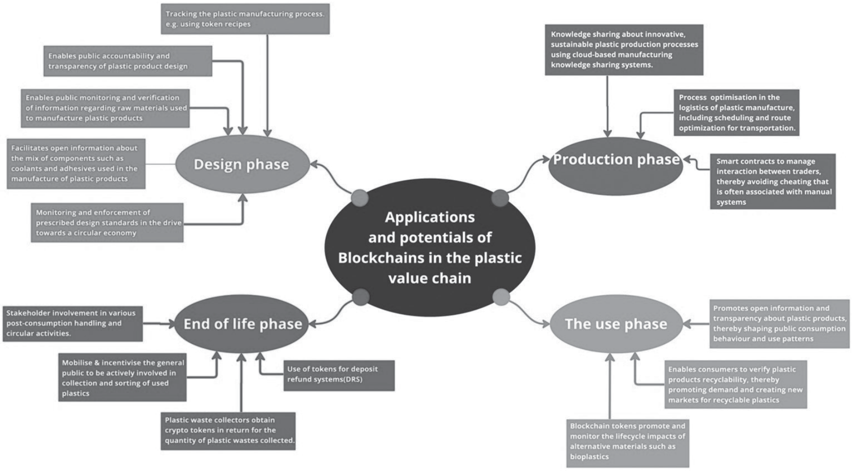

FIGURE 7.2 Blockchain applications in the plastic value chain (author)

support circularity and sustainability. This challenge is directly related to the lack of transparency about material composition, starting with the design of plastic products. Blockchain tokens can be used to track the plastic manufacturing process, including the composition of raw materials that underpin the design of plastic products. One innovative idea that has been recently proposed is the use of token recipes. This concept is based on representing physical materials, including raw materials, as digital tokens, and then identifying recipes that are used to transform the physical products (Westerkamp et al., 2020). As well as capturing the stages of tokenisation and recipes for product transformation, the process also includes certification of products to verify product standardisation and monitoring of compliance with regulations and quality control. For the design phase of the plastic value chain, token recipes, enabled by blockchain technology, enable public accountability and transparency of plastic product design. Other blockchain-enabled solutions that have been proposed include molecular tagging and digital product passport, through which plastic products can be traced from start to finish in a system that is immutable, transparent, secure and efficient (Bhubalan et al., 2022). In combination, these blockchain solutions enable public monitoring and verification of information regarding raw materials used to manufacture plastic products and open information about the mix of components such as coolants and adhesives that have been used in the manufacture of plastic products. It also enables regulators to monitor and enforce prescribed design standards in the drive towards a circular economy. Finally, transparent product design help to mitigate, if not entirely eliminate, one of the main challenges faced by other stakeholders further the value chain. This is achieved through verifiable product information that help in reuse, recycling and redesign of plastic products.

2.2.2 The production phase

The production phase of the plastic value chain is closely intertwined with the design phase. It entails physical and chemical combinations of polymers, along with other additives, adhesives and coolants, to manufacture products. In addition to information transparency about these constituent components, blockchain technology provides new opportunities for knowledge owners to share intellectual assets about novel, sustainable plastic production processes using, for example, cloud-based manufacturing knowledge-sharing systems (Li et al., 2018). In addition, blockchains can enable process optimisation in the logistics of plastic manufacturing process, including optimisation of transportation route maps and schedules, and the use of smart contracts to manage interaction between traders, thereby avoiding cheating that is often associated with manual systems (Xu and He, 2022).

2.2.3 The use phase

While entrenched societal habits of plastic use is influenced by the ubiquity of plastic products in the linear economy, consumption behaviour is also related to public awareness of, and ease of access to information about, the severe environmental impacts of plastic wastes. Thus, blockchain, by promoting open information and transparency about plastic products, can shape public consumption behaviour and use patterns (Boesen et al., 2019). One example is the Plastic Credit, a blockchain solution that enables consumers to verify the recyclability of plastic products, thereby promoting demand and creating new markets for recyclable plastics (Liu et al., 2021). Blockchain tokens can also promote and monitor the life cycle impacts of alternative materials such as bioplastics (Gerassimidou et al., 2022).

2.2.4 End-of-life phase

As mentioned in the introduction, the end-of-life phase is the phase in the plastic value chain that has attracted the biggest attention from a wide range of stakeholders. It is therefore the phase where blockchain technologies are finding the most active applications. Blockchain solutions are being used to involve stakeholders in various post-consumption handling and circular activities, including plastic waste collection, sorting, reuse, recycling and re-manufacture, among others. Blockchain technologies are being proposed to organise deposit refund systems (Reloop Platform, 2022). Blockchain tokens are also being used to mobilise and incentivise the general public, especially in low-income communities to be actively involved in collection and sorting of used plastics (Verma et al., 2022). Either in their own households or across the community, plastic waste collectors obtain crypto tokens in return for the quantity of plastic wastes collected. These tokens can then be exchanged for cash or used to access services.

3 Case study of BanQu, South Africa

3.1 Background

BanQu was founded in 2015 by Ashish Gadnis, a serial tech entrepreneur who was at the time working as a volunteer for the US Agency for International Development in the Democratic Republic of Congo. There, he had met a mother who could not secure a loan to pay her children's tuition. She was barely a farmer with considerable assets, but the bank rejected her scratch paper receipts as proof of sale for her loan application (Zhong, 2019). Gadnis recognised there the potential of digital currency to address the fundamental flaw in the global financial system that has, in effect, excluded a significant population of informal and micro entrepreneurs in developing countries. His brainchild, BanQu, is a blockchain-enabled supply chain solution which offers microenterprises and large organisations the opportunity to track and trace end-to-end transactions, covering "every mile", in a secure and transparent system (BanQu, 2022a). Among others, this digital solution enables enterprises to reduce costs and fix issues more quickly with real-time visibility in the supply chains, track raw materials and finished items from source to shelf to salvage and replace manual processes and paper-based documentation with tamper-free digital documentation and processes. BanQu has established itself as a blockchain platform of choice for refugees and people in extreme poverty. It is an accessible digital innovation that is driving integration of informal micro entrepreneurs from poorer and developing countries to the global economy (Sustainable Brands, 2016).

3.2 BanQu application for plastic waste management in Africa

In March 2021, Coca-Cola South Africa in partnership with BanQu launched a "payment platform to financially empower informal waste reclaimers and buyback centres in a boost to the local recycling sector" (Bulbulia, 2021). This initiative recognises the enormous contributions of otherwise invisible informal waste collectors to the circular economy. For more than 60,000 waste reclaimers in South Africa, BanQu solution enables them to create a permanent digital record of transactions, thereby enabling them to demonstrate their earnings in order to access credit. The BanQu solution enables low-risk, cashless transactions and generates public awareness about the contributions of waste collectors and buyback centres.

The BanQu payment solution is low tech in terms of accessibility, as users do not require expensive smartphones, and transactions are communicated via simple SMS. Users have given testimonials about the functional benefits they derive from the platform, including data-driven, strategic management of business operations. One recycling business owner notes:

> I thought the app would be a lot of work, but it makes things much more efficient with regard to data capturing, and the ins and outs and operations of my business, which I think is more important than anything … It allows us to have longevity

> because we know how to read the data. What are our trading volumes and how do we maintain them? If we drop, what can we do better? We can go back through our historical data records online and see what worked. I gained business insights that I didn't think I needed but which have come in very useful.
>
> *Refilwe Ramadikela, chief executive of Hendrina Recycling in Mpumalanga, South Africa, July 2022, IT Web Interview; IT Web, 2022*

The platform is also fully integrated with mobile money applications so that reclaimers can store their earnings in secure e-wallets and withdraw cash from ATMs (BanQu, 2022b). BanQu promotes financial inclusion of waste reclaimers and enables them to create financial records and credit history, giving them economic visibility in the global supply chain. It also enables owners of buyback centres to better understand and develop their businesses through the use of automated recording and tracking of transactions (Bulbulia, 2021). The payment solution is gaining traction in South Africa, and one key stakeholder has suggested that the data insights from the growing number of users registered on the platform, and the associated transactions, offer promising prospects for the future of the recyclable waste economy:

> With over R10 million worth of transactions representing over 4,000 tonnes of recyclables, we are beginning to reach a point at which our data has sufficient scale and diversity to provide a credible basis for analysis. By looking at this data, we can not only begin to understand the market better but also use these insights to support and grow the informal waste economy.
>
> *David Drew, PETCO vice-chairman and Coca-Cola's sustainability director for Africa July 2022, IT Web Interview (IT Web, 2022)*

4 Discussion

The BanQu case study underlines the point made previously that most of the attention and activities in the circular plastic economy has focused on the end-of-life phase of the plastic value chain. The BanQu blockchain solution has provided waste collectors with economic identity and visibility in the ecosystem. This has wide ranging implications, including the enactment of "dignity through identity" for otherwise unrecognised and excluded, yet important, economic actors (BanQu, 2017). The digital innovation has effectively demonstrated that it is possible to obtain better financial rewards from plastic waste collection activities, which many collectors have originally been pushed into because of unemployment, poverty and limited economic opportunities. With this development, stakeholders such as recycling centre owners and policymakers can mobilise more waste collectors and other participants into the circular plastic economy. In Spain, campaigners were able to mobilise citizens using virtual tokens and gamification for greater and more effective participation in the circular economy (Gibovic and Bikfalvi, 2021).

The BanQu technology can also enable other sectors of the wider circular economy through a complementary and mutually reinforcing mechanism. For example, with minimal tweaking, the BanQu solution can be deployed to link households discarding recoverable and reusable non-plastic items with collectors and enterprises who are able to reclaim value from the discarded items through recycling and refurbishment. Examples of such items include furniture, electronics, kitchen and other items that are sometimes discarded by higher income families but can be reclaimed and/or refurbished for use by others.

However, given the potential applications and reach of the BanQu digital solution for traceability and transparency, the technology has been significantly underutilised from the whole-value chain perspective in the South African case described above. There is no evidence that the solution has been applied yet in the earlier phases of the value chain, especially design and production of plastic products. Yet, the technology is highly promising in this area. There are two main factors that could possibly explain the relative lack of progress in these phases. The first is that, as reported, the project is jointly funded and led by Coca-Cola, a major multinational corporation producing plastic and other products. Coca-Cola would arguably be less invested in any application of the technology that will, in effect, demand more transparency and accountability from them regarding the design and production of plastic products. Conversely, investment in applications that incentivise other actors in the ecosystem to clean up the plastic "mess" is likely to be a more attractive area of investment for Coca-Cola. The other factor is the deficit of political will from governments and institutional actors to convene other stakeholders and apply appropriate policy instruments to drive interest in, and applications of, digital solutions for the earlier phases of the plastic value chain (Dokter et al., 2021). In other words, it will likely require the combined efforts of institutional actors and digital innovators, rather than big corporate sponsors, to lead the process through which blockchain solutions are applied and implemented in the earlier phases of the plastic value chain.

5 Conclusion

This chapter highlights the imperative of a whole-value chain approach to transitioning to a circular plastic economy, with blockchain technology as a key driver. Most of the current activities on the circular plastic economy have focused on the latter stages of the plastic value chain, especially the end-of-life phase. In the South African case discussed, blockchain technology has enabled stakeholders to empower otherwise invisible and unrecognised informal waste collectors, helping them to gain economy identity and create credit history, among others. This is significant and pathbreaking in many ways, not least in terms of the potentials to expand the circular plastic ecosystem and integrate millions of informal workers into national economies.

However, in other ways, the achievements on waste collection and recycling could be viewed as prioritising effects over causes or otherwise distracting from more critical causal problems. This is considering the fact that the increased volume of plastic wastes is a direct consequence of unsustainable design and manufacture of plastic products. Against this backdrop, therefore, this chapter argues that blockchain technology is a digital innovation of choice to invigorate the circular plastic campaign and redirect efforts in order to tackle the main causes of plastic pollution at their roots. First, with its key features of traceability and transparency, blockchains provide a platform to track and trace the design and production activities of big plastic producers. This will help consumers and the wider public to assess their level of commitment to the circularity agenda, as well as monitor their compliance with regulations and laws promoting a circular plastic economy. Finally, armed with this information about the design values and manufacturing activities of multinational plastic producers, informed and conscious consumers can take more targeted and concrete actions to enable and encourage manufacturers with high ratings on circularity and sustainable production practices.

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